Survivor

How do mutations or invasions affect populations?

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OVERVIEW

Students participate in an activity that models natural selection or the introduction of an invasive species by competing for limited "resources," and observing how the presence of an advantageous trait can change the class population over time. Students graph the population's change over time and participate in a guided discussion about factors that may influence natural selection.

OBJECTIVES & SKILLS ACQUIRED

At the conclusion of the lesson, students will be able to:

- Describe the effects of natural selection on a population, or the effects of an invasive species on a native population
- Understand the factors contributing to extinction, including displacement and competition
- Discern patterns of population growth, including exponential growth and the relationship between a population's environment and its carrying capacity
- Construct and interpret graphs relating to population growth
- Relate patterns to theory
- Use evidence to reason and draw conclusions
- Differentiate between a theory, hypothesis, and observation

LENGTH OF LESSON

50 minutes (30 minutes for activity + 20 minutes introduction and follow-up discussion)
If take-home questions are assigned, at least 10-15 minutes of further discussion may be desired in a subsequent class session.

GRADE LEVELS

3rd – 12th grade
(If used as invasive species model, grades 3-12. If used as natural selection model, may be used for grades 6-12)

STANDARDS COVERED

- S.IA.E/M.1 Inquiry Analysis
- S.IP.E/M.1 Inquiry Process
- L.EV.E.2 Survival
- L.EV.M.1 Species Adaptation and Survival
- L.EC.E.2 Changed Environment Effects
- L.HE.M.1 Inherited and Acquired Traits
- L.EC.M.1 Interactions of Organisms
- L.EC.M.2 Relationships of Organisms
- L.EC.M.3 Biotic and Abiotic Factors

STANDARDS COVERED (cont.)

B3: Interdependence of living systems and the environment

- L3.p1: Populations, communities, and ecosystems
- L3.p2: Relationships among organisms
  - - Competition
- L3.p3: Factors influencing ecosystems
  - - Population fluctuation, food web relationships
- B3.5: Populations
  - A) Graph population growth
  - B) Explain influences that affect population growth
  - C) Graph exponential growth and show carrying capacity
- B3.5x: Environmental factors
  - E) (Describe how physical/chemical environment may influence rate, extent, and nature of population dynamics)
  - F) Predict consequences of an invading organism on the survival of other organisms

B4: Genetics

- B4.4x: Genetic variation
  - A) Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and its offspring

B5: Evolution and biodiversity

- L5.p1: Survival and extinction
  - A) Define "species,"
  - B) Give examples
  - C) Define a population and identify local populations
  - D) Explain how extinction removes genes from a gene pool
- B5.1: Theory of Evolution
  - A) Summarize major concepts of evolution
  - B) Relate natural selection as a mechanism of evolution
  - E) Explain how natural selection leads to organisms that are well-suited to their environment
  - G) Illustrate how genetic variation is preserved or eliminated from a population through natural selection
- B5.3: Natural selection
  - A) Explain how natural selection acts on individuals, but it is populations that evolve.
  - B) Describe the role of geographic isolation in speciation.
  - C) Give examples of ways in which genetic variation and environmental factors are causes of evolution and diversity of organisms.
  - D) Explain how evolution through natural selection can result in changes in biodiversity.
  - E) Explain how changes at the gene level are the foundation for changes in populations and eventually the formation of new species.

BACKGROUND

What happens when a new species is introduced to an ecosystem, through invasion or a genetic mutation? The new species may be in direct competition with a native or established species for resources. This activity assumes that the new species can utilize resources more efficiently than native or established species, and is set up to demonstrate the effects of this competitive advantage over time. Possible outcomes include extinction of the established/native species, and a demonstration of exponential growth in the new species, over multiple rounds of the activity. Projections about further trials or rounds allow students to consider the fate of each species and to predict how growth will be inhibited by the carrying capacity. Upper-level classes can discuss the ability of the activity to actually model evolution.

MATERIALS

1. Red beanbags* x 1/3 total number of students in the class
2. Blue beanbags* x 1/3 total number of students in the class
3. Clipboard
4. Recording sheet (see attachment)
5. Bench or chairs – not necessary, but helpful for "dead" individuals

*Or any similar available objects

ACTIVITIES OF THE SESSION

Students play a game to explore the idea of mutation (or invasion, depending on which topic the teacher wishes to develop) and how the introduction of a novel and advantageous change in a gene can change a population or community over time, via competition for resources. In this scenario, students act as one of two types of organisms competing for resources. Small objects (e.g. beanbags) may be used to represent resources, and heterogeneous resource values are represented by contrasting colors of those objects. For instance, red objects are worth 2 life points, and blue objects are worth 1 life point. The number of "resources" should be ~2/3 the total class size, to represent competition for limited resources.

1. Explain that the students will be playing a game that models competition between 2 different species, and can be used to predict what would happen in this situation in nature. Tell the students that their job, as organisms in this game, is to survive and increase their population (If desired, students may be offered a reward for surviving throughout the duration of the game, and for gaining the most life points/producing the most offspring).
2. Designate a starting point, and place blue "resources" ~8 meters away, and red "resources" ~16 meters away.
3. Designate an "abiotic factor zone" where "dead" students will wait to rejoin the game as biotic factors (new organisms).
4. Set up the population ratio so that there are 2 "runners" for every 15 students in the class (Use 3 "runners" at >20 total students, and 4 as

class size approaches 30). All other students are designated as "hoppers," and must hop on 2 feet (like a kangaroo).

5. Explain the following rules of the game:
    a. Cheaters (e.g. "hoppers" who try to run) may be declared dead immediately
    b. Each student must attempt to acquire a single resource from either of the two resource areas.
    c. Blue resources are worth 1 point, and red resources are worth 2 points. Points for each student will be recorded at the end of every round.
    d. Any student who takes 2 resource items is automatically "dead"
    e. Any student that does not obtain a resource in a given round is considered "dead"
    f. For every 4 points gained by an active organism, they may recruit an individual from the "abiotic factor zone" to their respective species. This recruitment simulates reproduction.
    g. Students must wait in the "abiotic factor zone" in the order that they "died," and reenter the game in that same order.
    h. When a student reenters the game, none of their previously acquired points may count toward recruitment.
6. Explain that there are trade-offs in nature, and students may choose whatever strategy they wish (as long as the follow the rules outlined above) to survive or reproduce.
7. Give the command for students to begin running or hopping to obtain resources.
8. Run 5-7 rounds, replacing the resources after each round and using the same starting point each time.
9. At the end each round, record the points earned by each individual, and the population totals for each species, as well as the number of casualties for that round.
10. After returning to the classroom, make the data table available to the class and graph the population totals of each species for each round.
11. Discuss the outcome of the game (example discussion questions included below) and assign take home questions, if desired.

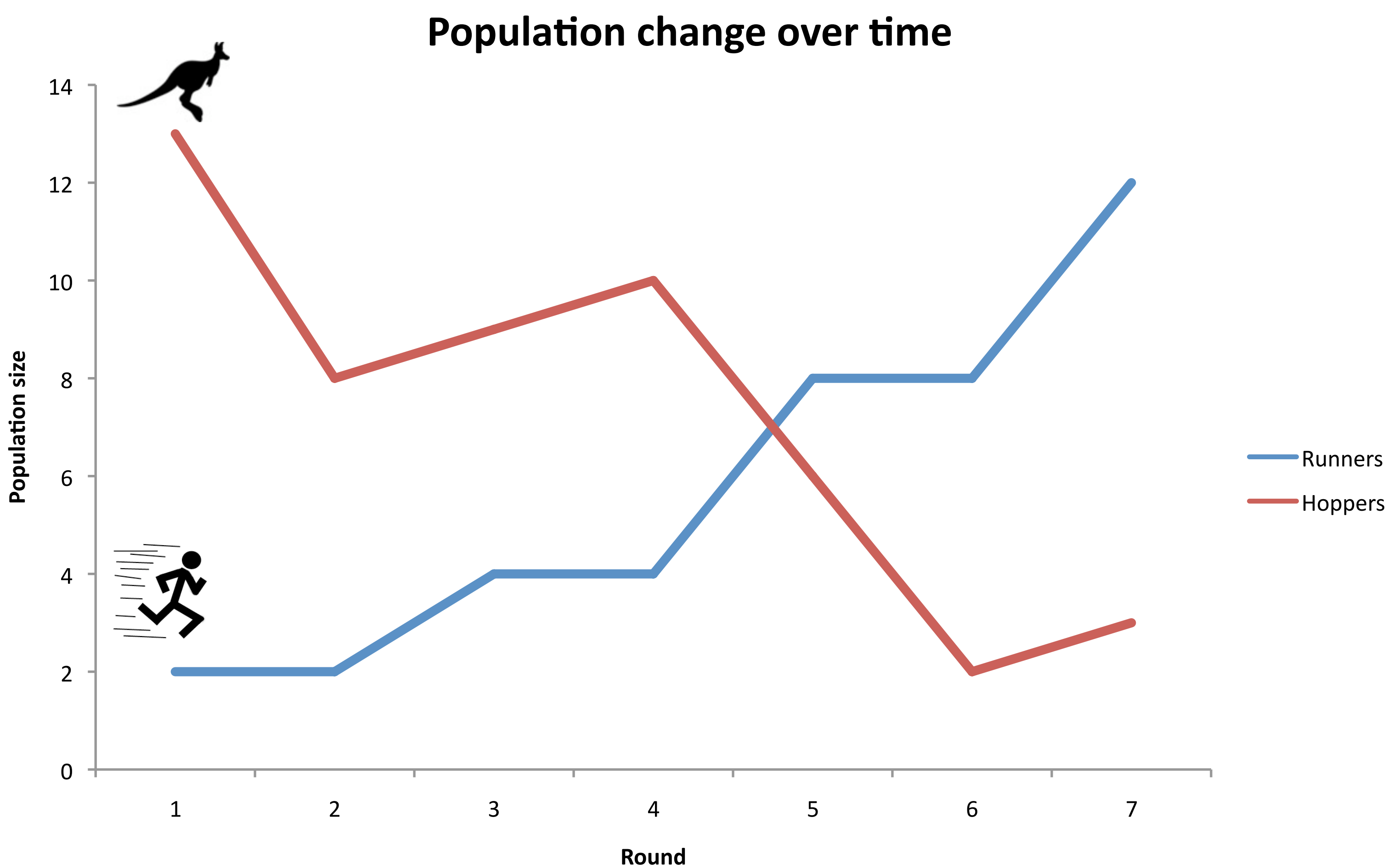
EXTENSIONS & MODIFICATIONS

- Any 2 colors (not necessarily red and blue) may be used
- For older students, the instructor may wish to have the "established species" walk heel-to-toe every step, rather than hopping.
- For younger age levels, replacing the term "reproduction" with "recruitment" may be appropriate

RESOURCES

Michigan Department of Education Science Curriculum Requirements:
http://www.michigan.gov/documents/BIOMMC_168213_7.pdf
Oh Deer! Project WILD sample activity:
http://wildlife.state.co.us/Education/TeacherResources/ProjectWild/OhDeer.html

Example



Population change over time
Population size
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
Round
Runners
Hoppers

Name	Round 1	Round 2	Round 3	Round 4	Round 5	Total points
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
subtotal						
Totals / species / round (after reproductions) Dead Runners Hoppers						**Final Total** Dead: Runners: Hoppers:

Protocol for using the Survivor game score sheet:

1. List student names in the “Name” column
2. In the line next to the student’s name, write 1 or 2 for the number of resource points that student earned in a given round, or write ‘x’ or ‘dead’ if the student did not acquire resources during that round.
3. At the bottom of the sheet, list the total number for each species, after all reproductions/recruitments have taken place. These numbers will be used to graph the population changes after the simulation is complete.
4. Use the subtotal line to keep track of each student’s cumulative points by summing points earned in the current round with the subtotal from the previous round. Remember that once a student earns 4 life points, s/he may reproduce, or recruit another student from the “abiotic factor zone” to his or her species. Once a student has used these 4 points, the subtotal begins again from 0. If a student has existing points but “dies” in a given round, s/he loses all points, and the subtotal begins again from 0.

“Survivor” natural selection game

Sample discussion questions (may be adjusted for varying levels of teaching)

1. What happened to the number of hoppers over time? What happened to the number of runners? Why do you think this happened?

2. How do you think the population will continue to change? Will the number of runners continue to grow exponentially? Discuss the fate of each species.

3. What were some of the different strategies employed in choosing resources? Did you always try to get the same color of resource?

4. What is the maximum combined number of hoppers or runners (i.e. Carrying capacity) that could be alive at the end of a given round? Why?

5. What do you think would happen if a predator were introduced? Discuss your reasons for your answer. Sketch a graph to illustrate your speculations. What other things besides predators might influence population growth?

6. What would happen if the people who were mutated into runners had instead been mutated into crawlers? What happens when a disadvantageous mutation is introduced into a population?

7. When does the new trait/individual become considered a species?

8. Assume this population of hoppers was geographically isolated, and has gone extinct due to being out-competed by the runners. There is an island where hoppers still flourish. What would happen if the new species, runners, were introduced onto this island? Are we certain that the same thing would happen as it did in the first encounter?

9. Devise a scenario in which the runner might be shown to actually be the ancestral species in this whole scenario.

Teacher Answer Key to the "Survivor" discussion/homework/classwork questions.

1. The number of hoppers reduced as time progressed in the game while the number of runners increased. The runners were out competing the hoppers, surviving at higher rates and consequently producing more offspring as well.

2. The runners will continue to dominate unless the environmental conditions change. Their population will grow unchecked and will appear to be exponential, eventually, however, they will only be competing with themselves and they will reach a balance with the resources available. This will show the carrying capacity and will restrict their population growth. The hoppers will likely be extinct from an area and may, at best, exist in low numbers. This will continue as long as they are directly competing (and losing) for the same resources with the runners.

3. Some hoppers did not try to go out farther to get "blue" (or the higher point value resources) because they knew they would not be successful so they consistently went for the close resources that were worth less but ensured survival. They would bide their time and eventually got to reproduce. Others went for it, risked survival but put more of an emphasis on reproduction and tried to gather enough points to reproduce/recruit more to their population. Runners would go for the big points but had the option of stopping for fewer points at the closest distance for easy success. Life was easier for them!

4. Carrying capacity is defined as the maximum size of a population that a particular environment can support. It is not a fixed number but varies over space and time with the abundance of limiting resources. The carrying capacity of this game would be determined by graphing the runners and finding where the population growth levels off and is being impacted by the abundance of the resources (limiting resources or limiting factors). If the resources are kept constant then that number is pretty much it. Variations of the game that change the resources from season to season would change this.

5. Part 1: A predator would keep populations from growing too large to quickly. Runners would not grow exponentially continuously if predators were increasing in response. Each population (runner to predator) would rise and fall cyclically in phase one after the other. If the predator were targeting both hoppers and runners then the hopper population may or may not be hurt by the predators unequally. Maybe hopping is a good defense that disorients the predator. Maybe it just makes them slower and they get eaten more. Answers can vary here with each argument.
   Part 2: Disturbances like floods, drought, fire, etc. in a certain area change the number of resources available and therefore effect the total population that can be carried.

6. The crawlers would be at a disadvantage and would likely not continue to survive unless an environmental change made them more likely to survive or some niche became open to them.
   If you are tracking a trait among the same species and the trait was one that was recessive or something similar, then it could still remain in the genome. It would pop up at various times/frequencies but as long as environmental conditions did not change, it would be a disadvantage at least.
   If the new "crawler" was a separate species that was reproductively isolated with pre-zygotic barriers (behavioral, mechanical, temporal, gametic or habitat isolation) or post-zygotic barriers (reduced hybrid viability, reduced hybrid fertility, or hybrid breakdown) then it would have to be able to compete to survive as a species.

7. I think the answer must involve a breeding population that is capable of existing on it's own. A new species is distinguished on the basis of reproductive incompatibility to the original species. A new species would have to be reproductively isolated with pre-zygotic barriers (behavioral, mechanical, temporal, gametic or habitat isolation) or post-zygotic barriers (reduced hybrid viability, reduced hybrid fertility, or hybrid breakdown) from the original species.

8. If "runners" did not take over as in the first scenario, then answers should suggest a possible explanation for why they might not take over. Maybe things like the brush on the island made it hard to run but hopping was an actual advantage would explain a reversal in fortunes.

9. Answers vary. Perhaps runners evolved into hoppers during conditions where predators chased them and hopping was more advantageous to avoid being targeted.